MANAGEMENT OF HIGH LEVEL RADIOACTIVE AND TRANSURANIC WASTE IN INDONESIA

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Abstract :*Indonesia's current strategy on fuel cycles is open c cle until a couple of decades after the operation of the first Nuclear Power nt (NPP). Therefore, there is no current and future reprocessing activities, so high level radioactive waste will be the spent fuel it self. At present, spent fuel from Research Reactors are re-exported to the origin country, the high level radioactive waste (HLW) are generated from Mo isotope production and radiometallurgy installations activities. Indonesia will assess with particular care the international development in LW management. The future spent fuel or HLW generated will be managed by interim and long term storage eventually, arrangements must be made for deep geological disposal.*

Keywords *: high level radioactive waste, transuranic waste, immobilisation of radioactive waste, storage and disposal, spent fuel n lear reactor.*

INTRODUCTION.

High Level Radioactive Waste (HLW) management comprises the activities related to the irradiated or spent fuel after its discharge from the reactor and thus included storage and disposal, with or without reprocessing. Indonesia's current strategy on the fuel cycles is open cycle until a couple decades after the operation of the first Nuclear Power Plant (NPP). Therefore, there is no current and future reprocessing activities [M.Iyos R. Subki and Gunandjar, 1994]. Reprocessing activities is a process to recover the remaining uranium (U) and plutonium (Pu) elements in spent fuels. In some countries which have reprocessing plant (closed fuel cycle strategy), the HLW are generated from the first cycle extraction of the spent fuel reprocessing plant. The type of HLW is High Level Liquid Waste (HLLW) which are contains fission product elements as major elements and transuranic elements as minor (contaminated) elements. In the first step of the reprocessing plant, is generation of High Level Solid Waste (HLSW) as the spent cladding. In the second cycle extraction, is generation of Transuranic Liquid Waste (TRULW). The composition of TRULW are transuranic elements as major elements and fission product as minor elements.

In some countries which have open fuel cycle strategy , such as Indonesia,

the HLW means the spent fuel it self. At present in Indonesia, spent fuel of research reactor are all re-exported to the origin country, the HLW are generated from Mo-isotope production at Radioisotope Production Plant (RPP) and post irradiation - examination of fuel at Radiometallurgy Installation (RMI). This paper explains current status of HLW management in the world and adaptation of HLW management technology, especially immobilization (encapsulation), interim storage, and disposal technology for HLW types in Indonesia which above mentioned.

CURRENT STATUS OF HLW MANAGEMENT IN THE WORLD.

The technology solutions favored arround the world for HLW management (with or without reprocessing) are the same, namely to leave spent fuel or wastes at surface level, cooling and decaying the radioactivity for 30

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– 60 years, and then isolate them safely from biosphere by placing in deep, stable, geological formations with a number of containment barriers.

a. Immobilization (Encapsulation).

The HLW immobilization to purpose for isolation of radionuclides from man and environment. The HLLW from reprocessing plant are usually in the form of nitric acid liquid. The nitric acid liquid has high acidity about 6 – 8 N. The volume of HLLW is reduced by evaporation, and the concentrated is solidified. The selection of matrix materials for immobilization of the HLLW is a complex decision with many factors to be taken into account, including : practically of the process, waste loading, radiation resistant, physical integrity, and leaching rates [Mendel J.E,1985].

The immobilization technology of HLLW by vitrification process has been operated industrially in many countries. At present, glass of borosilicate is utilized industrially for immobilization of HLLW. The glass of borosilicate has higher devitrification temperature and corrotion resistance than glass of phosphate, and also its waste loading higher than glass of aluminosilicate. Besides that, development of immobilization technology by synroc is in progress. The vitrification process relatively easier than synroc and vitromet process [IAEA, 1979]. Synroc is titanate mineral that has high chemical resistant. Development of synroc technology in technical scale is carried out in Australia, United Kingdom, and Japan in collaboration with Australia [IAEA, 1985].

Effort of developing new concept and technology toward the next stage of reprocessing HLLW is Super High Temperature Method (SHTM) of HLLW treatment. Treatment of HLLW by SHTM is dry process (separation – solidification in high temperature) created by JAEA – Japan [Horie M., 1990]. Its prime target is to realize solidification of high volume reduction without addition of matrix forming materials, making use of the fission products and actinides themselves contained in the HLLW as the solidification matrix. In addition, usefull elements are recovered at the same time. The processing temperature is 1600 ºC and the cold crucible is one of candidate forms of melting furnace. Melting of HLSW from spent fuel cladding is also being developed [PNC, 1995].

b. Storage and Disposal of HLW.

1. Interim Storage.

In case of open fuel cycle system or called once-through fuel cycle (no reprocessing activities), the HLW means the spent fuel it self. These spent fuel have to be stored for several decades (40 – 50 years) before final disposal. Interim storage can take place either in spent fuel storage at reactor site (AR site = at Reactor site) or at separate centralized facility out of reactor site (AFR site = at Away From the Reactor site).

Spent fuel storage technology has been developing for more than forty years. Most of the vast experiences that spent fuel has been accumulated with storage in water filled pool, but more recently dry storage techniques have been received widespread interest following claim of economic and safety advantages. Furthermore, the existing pools in many countries are not going to keep space with spent fuel arisings. To meet this requirement, a number of different concepts have been developed to increase the storage capacity, such as re-racking of existing pool and out of pool dry storage using cask, vault or concrete silo. Dry storage has been operated succesfully on a commercial basis in the United Kingdom since 1972 [M.Iyos R. Subki and Gunandjar, 1994].

Most spent fuel storage capacity is located at reactor sites for 5 years or more to provide a receptacle for emergency unloading of reactors, and also to allow for minimum cooling prior to transporting spent fuel to reprocessing facility or to longer term retrievable storage facility. Some countries consider a large centralized AFR storage facilities to which spent fuel can be sent after initial At Reactor (AR) cooling.

The technical and safety aspects of the various option for dry storage such as reliability, criticality, decay heat, radiation shielding, and

containment of radioactivity, are well known. It is expected also that the impact on the environment will be small.

The immobilization result of HLLW (waste-glass) have to be stored also in interim storage facilities for 30 – 50 years with cooling system [IAEA, 1979]. The cooling system is required to decrease high temperature of waste-glass. The high temperature is risen from radiation of radionuclides in waste-glass. If without cooling system or in the accident of cooling system, the temperature of waste-glass can reach more than 500 ºC which in a long term can make devitrification. The devitrification will increase the leaching rate of radionuclides from the waste-glass [IAEA, 1979]. Therefore, the devitrification have to be avoided by cooling system. Beside the purpose of storage until 50 years is also to avoid the high temperature of rock materials around pits in the disposal. Separation of cesium from HLLW by Super High Temperature Methode is to reduce interim storage period for 27 years [Horie M., 1990].

2. Final Disposal.

Most studies of spent fuel disposal envisage a period of interim storage (30 – 60 years) followed by encapsulation of the spent fuel in a corrosion-resistant canister which is then placed deep in repository in selected geological medium. Fuel elements are designed to retain fission products, and have very low corrosion rates. Therefore, spent fuel usually only requires packing in specially designed drum .

The disposal concepts is founded on a system of multiple, relatively independent barriers designed to ensure that the toxic radionuclides in the spent fuel remain isolated from man and environment at least until they have decays to levels which will prevent unacceptable risk to future generation, taking into account the possible release scenarios.

The various barriers have three main components, i.e : the near field, the geosphere and the biosphere. The near field consists of the stable waste form and a corrosion resistant package combined with immediate engineered barrier incorporated in the repository. The geosphere comprises the barrier presented by the host geological media. A key factor of the disposal media is the ability to restrict the flow of groundwater, hence low permeability or low flow regimes are considered, such as clay, salt and crystalline rock. The biosphere may not constitute a barrier in the strict sense of the word but would serve to dilute radioactivity. An understanding of pathways through the biosphere is also important for the prediction of the eventual fate of any radionuclides.

Radioactivity of elements in spent fuel and HLLW as function of time can be shown in Figure 1 and 2. Whereas, the correlation of decay heat output (in spent fuel of PWR and BWR) with decay time can be shown in Figure 3.

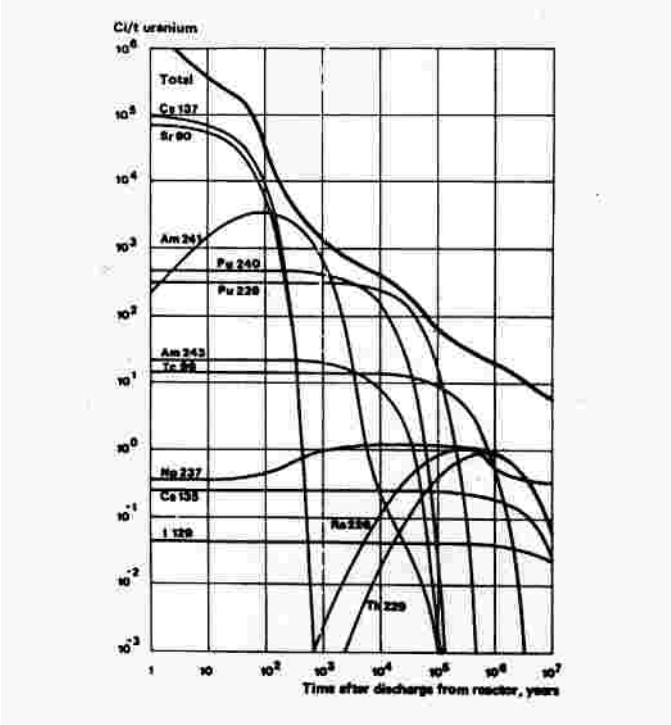

Figure 1. Radioactivity in spent fuel [Mattsson E., 1981].

From Figure 1 and 2, it can be concluded that HLW management (interim storage and final disposal) need one million years. Therefore, the engineering barrier (consist of glass matrix, canister, overpack, and bentonite buffer) and natural barrier (the host geological media) have to be able to prevent the radionuclides for along time mentioned above. Interim storage in pool system for 40 year can maintain the integrity of the spent fuel [SKBF, 1983].

ADAPTATION OF HLW AND TRANSURANIC WASTE MANAGEMENT TECHNOLOGY IN INDONESIA.

a. Sources and characteristics of HLW.

Indonesia's current strategy is that the fuel cycles strategies are to be open cycle until a couple of decades after operation of the first NPP. Therefore, the HLW means the spent fuel it self. At present, the spent fuel are generated from 3 research reactors, i.e.: The MTR type of Multipurpose Reactor G. A Siwabessy (MPR – GAS) _ located at Puspiptek area in Serpong, TRIGA Mark II type research reactor of 2 MW at Bandung, and small TRIGA Mark II type research reactor of 100 kW at Yogyakarta, see Table 1. The old one is TRIGA MARK II Reactor located at Bandung that critic at 250 kW in 1964, it was operated maximum at 1000 kW in 1971, and then was up-graded to 2000 kW in the year of 2000. Besides spent fuel from research reactor, the HLW are generated also from Radioisotope Production Plant (RPP) and Radiometallurgy Installation (RMI).

The HLW from RPP are usually in form of an acidic liquid (HLLW). They are generated from extraction process of Molybdenum Isotope production. Molybdenum isotope made from irradiation of uranium target (93 % U^{235}) in the reactor. Annual production of HLLW from RPP about 2 drum (120 liter) with total activity is 600 Ci. The major isotopes in HLLW are Ni^{99}, Ni^{63}, Fe^{55}, Mn^{54}, Co^{58}, Fe^{59}, and Cr^{51}.

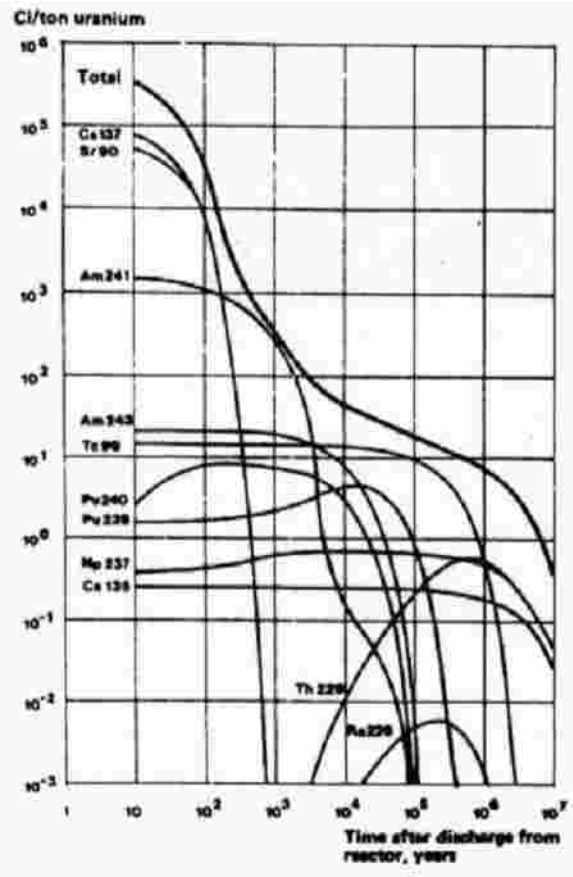

Figure 2. Radioactivity in High Level Liquid Waste [Mattsson E., 1981].

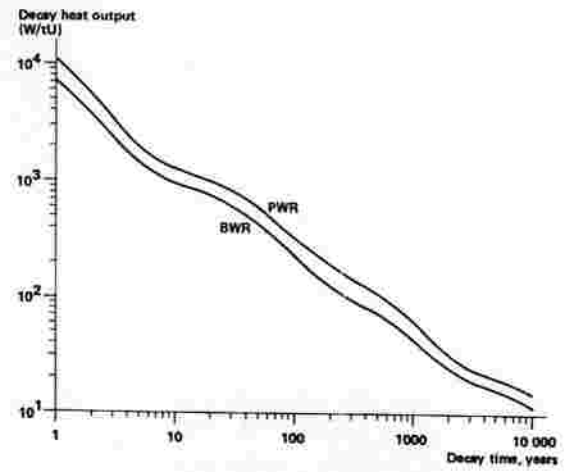

Figure 3. Decay heat out put per tonne U in spent PWR and BWR fuel declines with time [Mattsson E., 1981].

Table 1. Research Reactors in Indonesia.

Place	Marker	Type	Power	Critic	Status
Bandung	GA	TRIGA MARK II	2000 kW 1000 kW 250 kW	2000 1971 1964	Operation
Yogyakarta	GA	TRIGA MARK II	100 kW	1979	Operation
Serpong	Interatom	TRIGA MARK II	30 MW	1987	Operation

The HLW from RMI are usually in form of an acidic liquid (HLLW). They are generated from destructive test of irradiated fuel (Post Irradiation Examination of fuel elements). Annual production of HLLW from RMI about only 10 litre with total activity about 200 Ci. The major isotopes in the waste are Trans-Rare Uranic (TRU) or actinide and fission products (e.g. Cs^{137}, Sr^{90}, etc). In the future, the HLW from operation of NPP are in form of spent fuel.

b. Development of the HLW management technology.

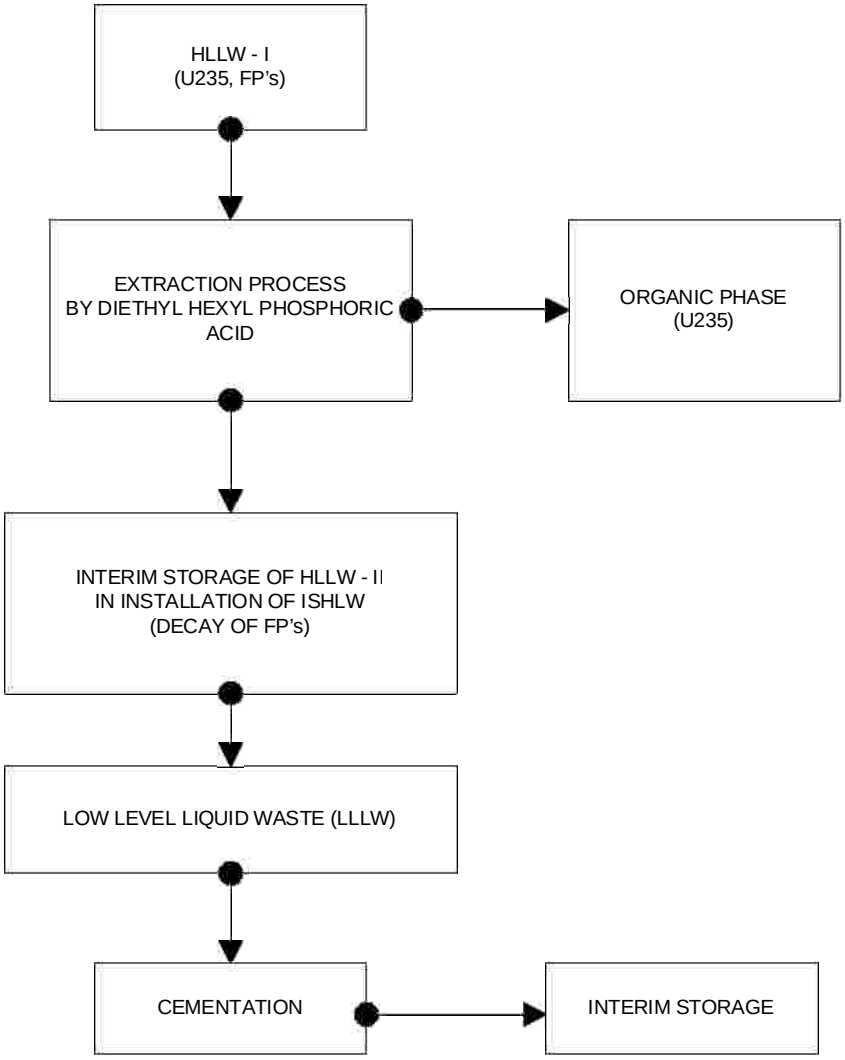

Figure 4. Treatment of High Level Liquid Waste from Radio Isotope Installation.

(1). Spent Fuel.
The spent fuel generated from research reactor (and NPP in the future) will be managed by interim storage and long term storage, eventually, arrangements must be made for deep geological disposal. Each NPP to be capable of providing 3-5 years of spent fuel storage pool at the NPP building. It is planned that spent fuels will be stored for further 40 - 50 years in Centralized Storage Facility at the NPP site [Soedyartomo Soentono et.al., 1999]. Indonesia will assess with particular share the international developments in deep disposal of spent fuel or HLW, to benefit from the experience in other countries. Then, the process of site selection for a waste repository will start at least ten years before such a repository might be needed.

Current status of spent fuel management are as follows : (a). The Interim Storage For Spent Fuel (ISFSF) has been built and put into cold commissioning in 1998. The ISFSF located near the Multipurpose Reactor G.A. Siwabessy (RSG-GAS) at Puspiptek area in Serpong. The capacity of the ISFSF is to be sufficient to store the spent fuel arising over 25 years reactor operation and unloading of the whole fuel in core since 8 fuels to be discharged per cycle for 7 cycles per year on reactor operation (8x7x25+48=1,448 elements). (b). According to the bilateral agreement between the governments of USA and Indonesia , the spent fuel having uranium originated from USA must be reexported back to USA. On March 1, 1999, 47 spent fuel elements from RSG-GAS have been sent to USA [Soedyartomo Soentono et.al., 1999]. After that followed by sending the amount of spent fuel elements generated from TRIGA MARK II Bandung and TRIGA MARK II Yogyakarta on the year of 2003.

(2). The HLW from Radioisotope Production Plant (RPP).
Development of management technology for HLLW from RPP can be shown in Figure 4. The remainder of U^{235} and fission products in HLLW–I are separated by extraction process using *diethyl hexyl phosphoric acid*. The waste to be filled on stainless steel drum (100 litre), then to be stored in dry well at Interim Storage for High Level Waste Facility (ISHLWF). Storage capacity of ISHLLWF is 200 drum

with activity 1500 Ci. The data of ISHLWF can be shown in Table 2. After storage for 1 – 4 years in ISHLLWF, HLLW–II become Low Level Liquid Waste (LLLW), and then can be immobilized by cement in 950 litre shell and stored in Interim Storage For Low and Intermediate Level Waste Facility (ISLILWF).

(3). The HLLW from Radiometallurgy Installation (RMI).

Vitrification technology is adapted for immobilization of HLLW from RMI. The waste contains fission products (FP's) and a small quantity of actinides. The actinide have to be separated by extraction process (using TBP + dodecane). The process will produce HLLW-II (contains FP's and a little of actinide) and LTRU waste (liquid transuranic waste) as organic phase contains actinide and a little of FP's. The immobilization of HLLW-II by vitrification (using borosilicate glass) and LTRU waste by polymerization. Treatment of HLLW from RMI can be shown in Figure 5.

The Research & Development of vitrification and immobilization technology have been being carried out in Radioactve Waste Technology Center – BATAN. Immobilization of LTRU waste by polymer were developed using polymer acrylic epoxy (Martono H, Danu S., 1993), polyester of styrene (Martono H., Danu S., 1994), styrene divinyl benzene (Martono H., 1995), and resin epoxy (besphenol-A-diglysil diether (Aisyah et.al., 2004). Results of the immobilization development of LTRU waste can be shown in

Table 2 . nterim Storage For High Level Waste Facilities (ISHLWF)

o.	I T E M	S P E C I F I C A T I O N
1	ISHLWF	Dimension : 6.5 m x 24 m x 6 m
2	Wall (concrete)	Thickness : 70 cm Specific Mass : 3.0 ton/m^3
3	Storage	Capacity : 200 drum with activity 15,000 Ci
4	Dry well	Dimension : diameter = 60 cm depth = 6 m thickness = 10 cm

Table 3 . Data of The Immobilization Development for Liquid Tr nsuranic Wastes.

Polymer	Leaching Rate ($g.cm^{-2}.day^{-1}$)	Waste Loading (%)	Compresive Strength ($kN.cm^{-2}$)
Acrylic Epoxy	0,3784	30	14
Polyester of Styrene	0,0018	30	14
Styrene divinyl benzene	0,0046	40	21.75
Resin Epoxy (Besphenol-A-diglysil diether)	No detection	30	43.10

Table 3. From the results shown that compression strength, leaching rate of polymer contains waste are comply to standard. Waste loading is high so those are economics in immobilization process.

CONCLUSION.

Indonesia's current strategy is that the fuel cycle strategies are to be open cycles until a couple of decades after operation of the first NPP, therefore HLW means the spent fuel it self. The spent fuels generated will be managed by interim and long term storage, eventually, arrangements must be made for deep geological disposal.

Each NPP is capable to provide 3-5 years of spent fuel storage pool at the NPP building. It is planned that spent fuels will be stored for further 40-50 years in Centralized Storage Facility at the NPP site. The process of site selection for a waste repository will be start at least ten years before such a repository might be needed.

The HLLW from radioisotope production plant (RPP) and radiometallurgy installation (RMI) will be stored in dry well at interim storage for high level waste facility (ISHLWF). After 1 – 2 years, the HLLW from RPP can be categorized as LLLW, then they can be immobilized by cement in 950 liter shell and stored in interim LLW storage facility. Where as, the HLLW from RMI the actinide have to be separated by extraction proses (using TBP+dodecane), and then the HLLW-II which contains FP's and little of actinide can be immobilized by vitrification and LTRU waste by polimerization.

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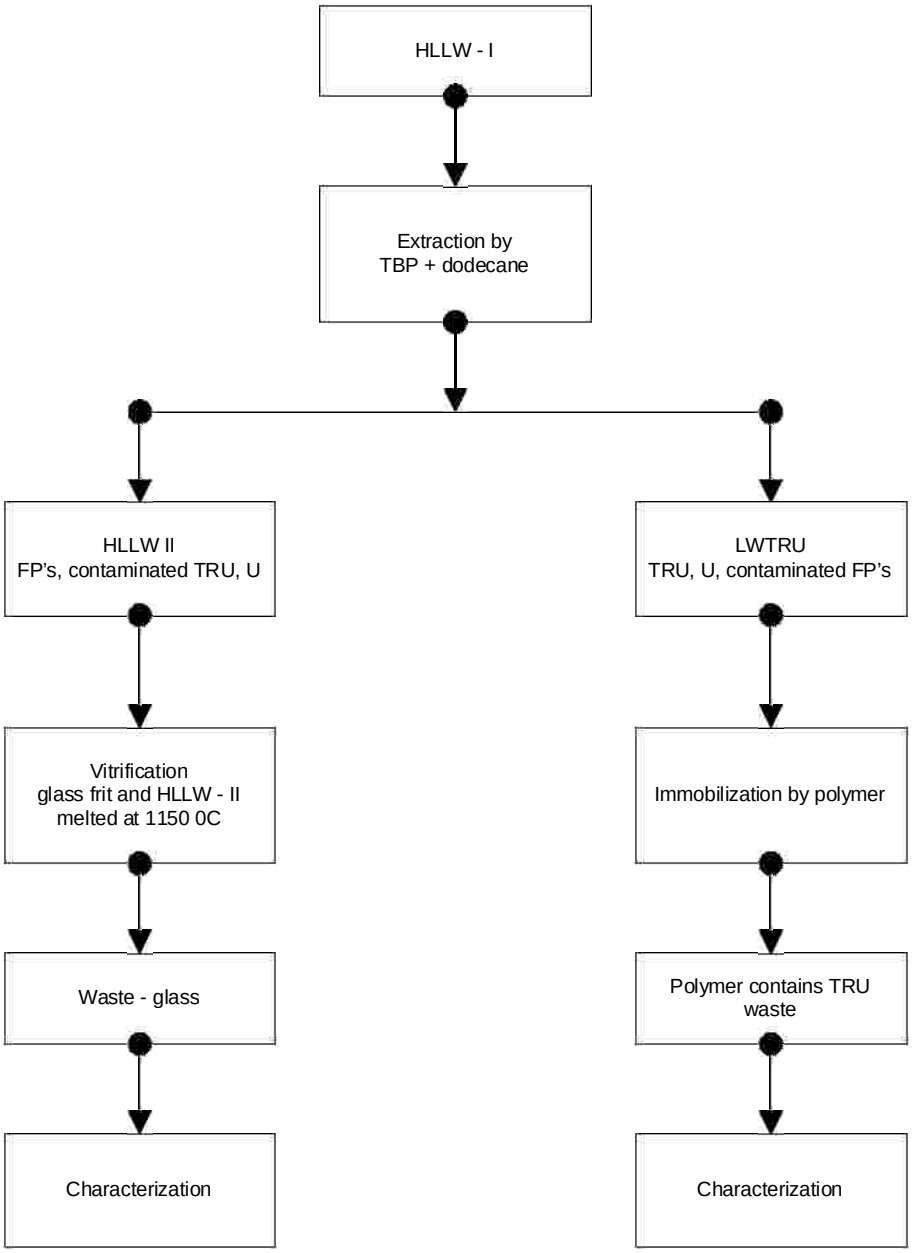

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